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INFORMATION CIRCULAR 38

Pennsylvania Geological Survey
Fourth Series

GEOLOGIC INTERPRETATION of AEROMAGNETIC MAPS

TEMPLE, FLEETWOOD, MANATAWNY, READING, BIRDSBORO, & BOYERTOWN QUADRANGLES

by

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FOREWORD

Southeastern Pennsylvania is an area of extremely varied and complex geology with a long history of mineral production. The list of mineral commodities which this area has yielded at various times is considerable, but iron-ore stands out as the most prominent. Scores of iron mines and furnaces have operated in this area in the past 200 years. With a record of production dating back to Pre-Revolutionary War years, the mine at Cornwall is the oldest continuously operating iron mine in the United States. The recent development of the large and magnificent Grace Mine at Morgantown is living testimony to the fact that Pennsylvania's metallic mining record is not simply a story of the past. Through modern methods of exploration and research, new mineral resources remain to be found.

The Bureau of Topographic and Geologic Survey of the Department of Internal Affairs is pleased to have participated and cooperated with the United States Geological Survey in carrying out an aeromagnetic survey of Southeastern Pennsylvania. This modern exploration technique is particularly well suited to the geologic conditions and to the potential mineral resources of the area; it is an extremely efficient method of acquiring geologic data for a large region. The results of the aeromagnetic survey are being published by the United States Geological Survey as a series of aeromagnetic contour maps.

We are pleased to present this publication as a service to the Commonwealth of Pennsylvania. It is hoped that this interpretation and discussion of the aeromagnetic maps will serve as a stimulus for further research and development.

Genevieve Blatt

Genevieve Blatt, Secretary
Department of Internal Affairs

GEOLOGIC INTERPRETATION OF AEROMAGNETIC MAPS TEMPLE, FLEETWOOD, MANATAWNY, READING, BIRDSBORO, AND BOYERTOWN QUADRANGLES

General Statement

The magnetic contour maps being discussed in this series of publications are the result of a cooperative project of the United States Geological Survey and the Pennsylvania Geological Survey, Department of Internal Affairs. About 5,000 square miles of southeastern Pennsylvania have been covered in this survey, the results of which are being published as individual 7 1/2-minute quadrangle maps.

This information circular is one of a series intended as a preliminary explanation of the interrelation of distinctive magnetic features with geological conditions in each quadrangle. In many instances unusual magnetic patterns can be explained by geological features which have been mapped and studied in the past. It is hoped that the map viewer will not only be aided by such correlation of data, but that this publication may stimulate exploration and research in those areas where there is at present no known or satisfactory geological explanation for some of the magnetic features which appear on the magnetic contour map. Such exploration and research could directly or indirectly lead to discovery and development of new mineral deposits and would greatly further the basic knowledge of the geology of Pennsylvania.

The magnetic contour lines on the map are lines connecting points of equal magnetic intensity. The shape, position, and spacing of the magnetic lines are due to the combined effects of the earth itself, which is a huge magnet, and to the local variations in the magnetism of the rocks underlying any given area. If only the earth as a large, uniform body were responsibile for the magnetic lines, they would be essentially straight and simple. It is the local geology, however, which imparts complexities to the patterns of the magnetic lines. Such complexities or variations from a simple pattern are called anomalies.

Local magnetic effects vary from place to place because the magnetic properties of the respective rocks are not alike or because differences in rock structure from place to place change the magnetism measured at the surface. Rocks which have different kinds or different relative amounts of minerals, particularly iron-bearing minerals, have unlike magnetic properties. In general, the more iron minerals present, the stronger the magnetic effect. The iron oxide mineral, magnetite, has a strong magnetic effect even when present in small quantities; when present in large amounts, magnetite is of economic interest as a possible iron ore.

If in a given area the rocks have been folded or faulted by internal earth forces, the resulting variation in position of the different rocks will be indicated by variation in magnetic readings from place to place. Thus, structural complexities as well as mineral variations may be revealed by the magnetic data. Of particular interest are those magnetic variations or anomalies which are circular or tend to enclose a given area; the implication in such cases is that there is a specific, localized causative factor more or less pin-pointed by such a pattern.

The aeromagnetic survey of southeastern Pennsylvania was carried out with the use of an airborne magnetometer, an instrument towed by a plane. The plane covered the area by flying back and forth along straight, parallel flight lines spaced a quarter mile apart. An attempt was made to maintain an elevation of 500 feet, above the ground so as to eliminate magnetic changes due solely to terrain changes. An airborne magnetic survey has the advantage of eliminating very minor magnetic features on the ground, thus permitting a better evaluation of larger and deeper magnetic phenomena. It should be borne in mind that the instruments which have measured the magnetic effects in these studies are very sensitive and capable of detecting small changes. Proper evaluation of these changes is necessary to distinguish those situations which offer possibilities for economic mineral development from those cases where the information yielded is of more academic interest.

Temple University
U. S. Geological Survey Aeromagnetic Map G. P. 227

The aeromagnetic contour patterns on the map of the Temple quadrangle show a correlation with the major structural units and rock types. In the southeast quarter of the quadrangle is part of the so-called Reading Prong; it is a complex area of crystalline rocks with infolded or infaulted Hardyston sandstone with associated large, closely-space anomalies. The rest of the quadrangle, which is underlain by much less deformed limestones and shales of Cambrian and Ordovician age, exhibits no magnetic contour lines, an indication of uniformly low magnetic intensity.

A large, oval-shaped, positive magnetic anomaly occurs over Irish Mountain; northeast of Temple in Muhlenberg Township. The anomaly is nearly two miles long and a mile wide, with an amplitude of 600 gammas. Irish Mountain is a prominent topographic feature which owes its relief to erosion-resistant Hardyston quartzite. The Hardyston Formation, not unlike the Antietam Formation farther to the south in Lancaster County, has been found in certain places to carry disseminated magnetite in the basal members. It has been suggested that this is the result of metamorphism of sedimentary hematite. The presence of a small amount of magnetite in the Hardyston at Irish Mountain, accentuated by the topographic effect, could account for the magnetic anomaly there. Neither the rock types present nor the characteristics of the anomaly offer encouragement as to the possibility of an iron concentration of minable proportions.

Two small, positive magnetic anomalies occur near the eastern edge of the quadrangle along the Muhlenberg-Alsace Township line east of Temple. Each of these has an east-northeasterly trend, is less than a mile long, and has an amplitude of about 300 gammas. These occur over hornblende granite gneiss which has small but variable amounts of disseminated magnetite present. In many instances, the darker, horneblende-rich zones in the gneiss also carry more of the disseminated magnetite. At best, no more than a few percent of magnetic iron is present in these anomaly areas

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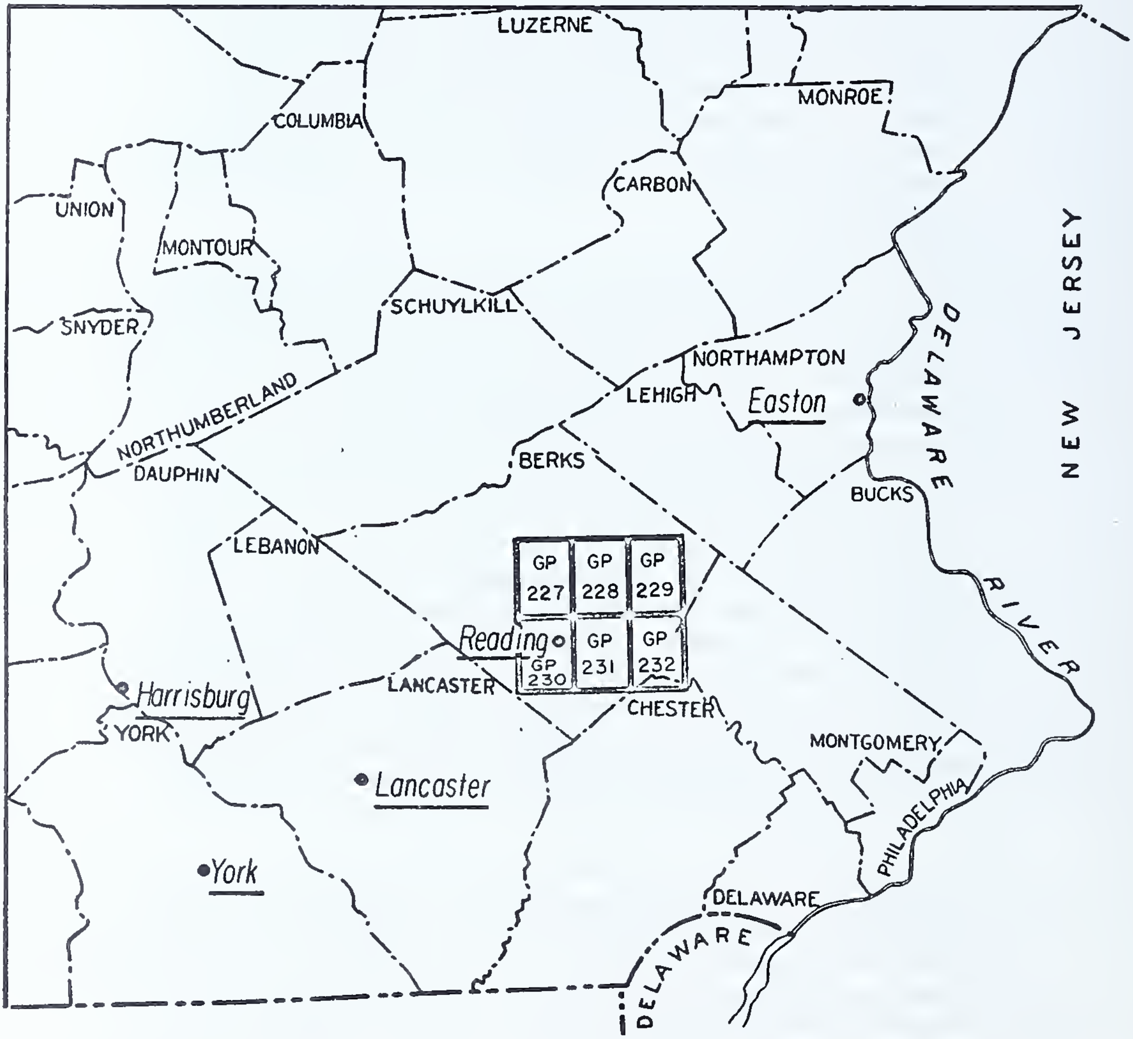

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and neither the size nor the amplitude of the anomalies offer any indication of economically significant concentrations of iron minerals.

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Fleetwood Quadrangle
U. S. Geological Survey Aeromagnetic Map G. P. 228

The magnetic patterns on the Fleetwood quadrangle magnetic map tend to define the major rock types. The northern third of the map and the southeast corner exhibit only a few, widely spaced magnetic contour lines; that is where Cambro-Ordovician limestones occur. The rest of the quadrangle exhibits closely spaced magnetic contours and numerous anomalies of various sizes and shapes; this corresponds to the area underlain by various crystalline rocks and infolded or infaulted Cambrian quartzites.

A small positive magnetic anomaly occurs about a half mile east of the town of Alsace Manor. The anomaly has an amplitude of 150 gammas. Another positive anomaly occurs at nearby Breezy Corner in Ruscombmanor Township; here too the amplitude is about 150 gammas and the length of the anomaly is about a half mile. A mile north of Breezy Corner an elongate positive anomaly occurs along the north flank of Sand Hill; here the anomaly has an amplitude of 500 gammas and a length of 2 miles. In the case of each of the three anomalies just cited, the underlying rock is crystalline, granitic gneiss. This material locally varies considerably in composition, in places carrying small concentrations of iron-bearing minerals, including magnetite, which could readily account for these relatively small anomalies. No iron concentrations of economic importance are indicated here.

A small positive magnetic anomaly of 200 gammas amplitude occurs a half mile northeast of Pricetown in Ruscombmanor Township. Just to the east, near Seidel School, is another positive anomaly, about a half mile long with an amplitude of about 200 gammas. A mile further east, near Keller School, is another anomaly with an amplitude of 300 gammas. These three anomalies, essentially in an east-west line, are all located over granitic gneiss and are probably due to relatively minor, local concentrations of magnetite; D'Invilliers (1883) records some iron prospects here. No concentrations of economic proportions are indicated either by the extent of the anomalies or the limited occurrence of the magnetite.

Near Sheep Hill in Rockland Township is a positive anomaly about a half mile long with an amplitude of 300 gammas. An extension of this anomaly appears to trend westward for about 2 miles. Here too, the anomaly appears to be due to a minor concentration of iron-bearing minerals in the underlying granitic gneiss; no economic potential is indicated.

An elongate positive magnetic anomaly can be traced for nearly 3 miles along the south flank of Furnace Hill near Oley Furnace. The anomaly is developed over a belt of gneiss rich in hornblende and with local concentrations of magnetite. Several small mines were attempted in this zone prior to 1900: the Clymer Mine, the Tunnel Mine, the Yoder Mine and the Swoyer Mine. They encountered a layer of crystalline magnetite ore up to 5 feet thick which yielded material running as high as 59 percent metallic iron. The ore apparently occurred in the gneiss at the contact with the quartzite which makes up Furnace Hill. The anomaly suggests that some magnetite (and probably other iron minerals) still exists along the south flank of Furnace Hill but neither the anomaly nor the relatively limited occurrence of the magnetite which has been observed offer any encouragement as to the likelihood of a concentration here of economic proportions.

Just west of the town of Oley in the southeast corner of the quadrangle is a positive anomaly about a mile in diameter with an amplitude of 300 gammas. The anomaly straddles the contact between the old, crystalline, granite gneiss and the Ordovician Martinsburg shale. The form of the anomaly is characteristic of the granite gneiss and thus it appears that the gneiss extends under the shale at a shallow depth. The anomaly indicates that only a minor concentration of iron minerals exists in the gneiss; no magnetite of economic proportions is at all indicated.

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Manatawny Quadrangle
U. S. Geological Survey Aeromagnetic Map G. P. 229

The Manatawny quadrangle is underlain predominantly by old, crystalline gneisses. Infolded or infaulted into these gneisses are areas of Cambrian-age Hardyston quartzite. In each of the four corners of the quadrangle are areas of Cambro-Ordovician limestones.

The magnetic map of the Manatawny quadrangle exhibits a pattern with a number of magnetic anomalies which in overall distribution corresponds with the large area of Precambrian gneisses. The anomalies are of various sizes, shapes,amplitudes,and orientations.

The outstanding positive magnetic anomaly of the quadrangle is at Rittenhouse Gap along the eastern edge of the quadrangle. The anomaly extends onto the adjacent East Greenville quadrangle (U. S. Geological Survey Aeromagnetic Map G. P. 205). The Rittenhouse Gap anomaly has an amplitude of about 3000 gammas, one of the largest found in the entire aeromagnetic survey of southeastern Pennsylvania. During the 1870's and 1880's the Rittenhouse Gap district was the site of over 100 mines, which produced over half a million tons of magnetite ore per year. D'Invilliers (1993) gives a fairly detailed account of the major mines, their underground workings, and the nature of the ore. The Gery Mine, the Ginkinger Mine, the Rittenhouse Mine and the Miller Mine were some of the more impressive operations in this small area. Most of the mines originated as open pit operations which were then extended underground by shafts due to the steep dip of the ore zones; fairly extensive underground workings at various levels are reported. The magnetite ore zones tended to pinch and swell, attaining thicknesses of up to 30 feet. The ore zones in each case reportedly dipped about 60° to the southeast and within each band the ore tended to be concentrated in shoots pitching to the northeast. The ore was followed to depths of around 150 feet where some of the zones pinched out. The contacts between ore and country rock tends to be transitional rather than sharp; ore samples can be collected which show all degrees of concentration from nearly pure magnetite to gneiss rich in quartz, hornblende, mica, and feldspar. Several analyses of ore from the district show a range in composition as follows:

metallic iron	30-52%
sulfur	.002-1.75%
phosphorous	.006-.06%
silica	24-51%
alumina	.2-8%
magnesia	.4-9.8%

Most of the gneissic country rocks in the Rittenhouse Gap area appears to be meta-sedimentary, though some of the gneissic layers may have an igneous origin. The presence of pegmatites indicates igneous or near-igneous activity.

After an extensive examination of the Rittenhouse Gap area in 1918, a geologist estimated 400,000 tons of possible ore which would average 23% iron content. At that time the underground workings were somewhat more accessible than they are today and the report comments on the large number of lenticular ore zones as well as the gneissic country rock which invariably contains 5% magnetite even in the more barren zones.

Today, many of the large open cuts and pits in the Rittenhouse Gap area are still accessible but the underground workings are partially caved and flooded.

The extent and the amplitude of the Rittenhouse Gap anomaly command serious attention. A major concentration of magnetite is indicated at a relatively shallow depth, with the ore horizon dipping to the southeast. A preliminary field examination in the area indicates that there are significant fault and fold structures which may play a role in the present distribution of the ore zones as well as the original localization of the ore. It is noteworthy that though the gneissic foliation strikes to the northeast, there are indications that the old mines are lined up along some type of north-south lineaments. This is an area in which further exploration, mapping, and drilling may be warranted to establish the actual size and grade of the ore zones.

A mile south of Topton, in Longswamp Township, there is a positive magnetic anomaly nearly a mile long with an amplitude of about 400 gammas. This anomaly occurs over a small area of graphitic granite gneiss which carries some magnetite. An attempt was made to mine some magnetite stringers here in the 1880's but the mineralization was extremely thin and discontinuous. The small amplitude of the anomaly as well as the geologic nature of this rock type offer no indications of a significant iron concentration.

A small, positive anomaly a half mile west of Lower Longswamp occurs over an area of Hardyston quartzite. Though the basal Hardyston has been found locally to contain small iron concentrations, this anomaly is similar in character to those associated with the gneisses in the area; it suggests that gneiss may exist at a relatively shallow depth under the quartzite. No significant concentration of iron is indicated, however.

A northeast-trending, double-peaked positive anomaly occurs astride the Longswamp-District Township line about a mile southwest of Rittenhouse Gap. This anomaly is over a mile long and has an amplitude of about 900 gammas. The anomaly occurs over granite gneiss and trends parallel to the gneissic foliation. This gneiss locally carries thin stringers and bands somewhat enriched in magnetite. However, the magnetic and geologic evidence at this site do not indicate commercially significant concentrations of iron.

A half mile north of Landis Store in District Township is a north-trending positive anomaly with an amplitude of over 500 gammas. This is an area of graphitic, granitic gneiss and the anomaly trends parallel to the gneissic foliation. The indications are that a band in the gneiss, somewhat enriched in magnetite, is responsible for the anomaly. Neither the rock type nor the anomaly suggest any significant concentration of magnetite.

A mile northeast of Landis Store, at the District-Hereford Township Line, there is a positive magnetic anomaly of about 300 gammas amplitude. This is an area underlain by hornblende gneiss, including a small amount of disseminated magnetite. Neither the small amplitude of the anomaly nor the rock type suggest significant iron mineralization here.

A fairly large, double-peaked, positive magnetic anomaly occurs in the southeast corner of the map at the intersection of the District, Pike, and Washington Townships. The anomaly is nearly 2 miles long and occurs over an area of hornblende-rich gneiss which locally carries concentrations of disseminated magnetite. D'Invilliers (1883) reports on the Gilbert and Gilberg Mines in this area, from which titaniferous magnetite was mines in the 1880's. The mines were apparently not too successful even then. Neither the small amplitude of the anomaly nor the local geologic conditions offer any encouragement as to commercially usable iron concentrations here.

A large, positive magnetic anomaly occurs a mile north of Hill Church in Pike Township. The anomaly is 2 miles long and has an amplitude of about 300 gammas. This is a broad feature of relatively low amplitude which occurs over an area of hornblende gneiss. Some disseminated accessory magnetite occurs in the rock but the indications are that only a very minor concentration of iron exists here.

Three positive magnetic anomalies are lined up in a northeastern trend extending across Pike Township into District Township. One anomaly peals occurs just northwest of Pikeville in Pike Township; the second peak is a mile northeast of Pikeville; the third peak is just west of Landis Store in District Township. These anomalies are developed over a topographic ridge made up of hornblende-bearing gneiss with some accessory titaniferous magnetite. The anomalies have amplitudes of less than 300 gammas and the indications are that there is no significant iron concentration here.

Along the western edge of the quadrangle, there is a positive magnetic anomaly north of Lobachsville, near the Rockland-Pike Township line and extending northward to Rupperts School. The underlying rock is hornblende gneiss which locally carries bands of titaniferous magnetite. These iron-rich zones have not been found thick enough to utilize by modern iron mining standards and the titanium content is particularly undesirable. Neither the anomaly nor the geologic conditions offer any encouragement as to commercially significant iron concentrations at this locality.

A mile east-southeast of New Jerusalem in Rockland Township is an elongate, double-peaked, positive anomaly.

The anomaly trends eastward for a mile and a half and has an amplitude of about 300 gammas; it appears to be developed along a shear zone in hornblende gneiss (Buckwalter, 1959). Accessory magnetite is fairly common in this rock but neither the anomaly nor the local geology indicate any significant concentration here.

A mile and a half east of Dryville in Rockland Township there is a positive magnetic anomaly nearly a mile in diameter with an amplitude of about 300 gammas. The underlying rock is hornblende-rich gneiss which carries some accessory magnetite. Neither the anomaly nor the local geologic conditions indicate any economically significant iron concentration here.

A mile south of Fredericksville, along the Rockland-District Township line, there is a double-peaked positive magnetic anomaly trending northeasterly for a mile and a half. The higher, more southerly peak has an amplitude of about 500 gammas. This anomaly is underlain by a topographic ridge of hornblende gneiss and was the site of the Butler iron mine in the 1880's (D'Invilliers, 1883). The mine went to a depth of 240 feet, following a 10-12 foot thick bed of granular, titaniferous magnetite within the gneiss. Within the area is a second ore bed 3 feet thick. About 10 tons a day was mined for several years before the mine was abandoned. The pyrite, feldspar, and quartz gangue within the ore made it difficult to handle. Though the anomaly indicates that some mineralization remains here, the gangue minerals, the very high titanium content, and the relatively limited thickness all are very unfavorable conditions in relation to modern iron mining requirements.

A mile east of Fredericksville in District Township there is a prominent positive magnetic anomaly over a half mile in diameter with an amplitude of about 400 gammas. A half mile due south is another positive anomaly of about 300 gammas amplitude. These anomalies are both over hornblende gneiss which also carries disseminated titaniferous magnetite. The more southerly of these two anomalies is the site of the old Trexler Mine which attempted to develop a titaniferous magnetite zone in the gneiss. The mine was apparently unsuccessful then (1880's) and though the anomalies suggest some iron mineralization still exists, the limited thickness of the magnetite zones, the considerable and undesirable gangue, and the highly undesirable titanium, all are conditions which are unfavorable for modern iron ore requirements.

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Reading Quadrangle
U. S. Geological Survey Aeromagnetic Map G. P. 230

The Reading quadrangle is an area which involves several distinct structural and lithologic units, each of which develops its own magnetic pattern. The northwest quarter of the quadrangle shows only a couple of very widely-spaced contours; this is an area underlain by Cambrian and Ordovician limestones and shales with uniformly low magnetic intensity.

The northeast corner of the quadrangle shows several pronounced, closely-spaced anomalies; this is an area with considerable topographic relief, underlain by highly deformed, old crystalline gneisses of the so-called Reading Prong.

The southern part of the quadrangle is an area of Triassic sediments and igneous (diabase) dikes. The sedimentary areas develop only a few, widely-spaced magnetic contours due to their uniformly low magnetic intensity. The intrusive diabase, however, is responsible for a pattern of closely spaced magnetic contours running easterly across the south-central part of the map.

A large, positive magnetic anomaly occurs over Mount Penn in Lower Alsace Township, just east of the City of Reading. The anomaly is over a mile long and has an amplitude of 700 gammas. The anomaly is centered over the contact between Hardyston quartzite and hornblende-granite gneiss. The Hardyston Formation, whose erosion resistance is partly responsible for the topographic expression of Mount Penn, and the hornblende-granite gneiss are both known to carry bands which are somewhat enriched in magnetite. The magnetite is disseminated and rarely extensive in size or grade. The Mount Penn anomaly is probably intensified as a result of the topographic effect of the mountain. Neither the general geologic conditions nor the nature of the anomaly offer encouragement as to the likelihood of an important iron concentration at this locality.

About a mile south of the Mount Penn anomaly there is a curved, almost hook-shaped positive anomaly which is developed over an unnamed ridge lying just west of Pennside along the eastern edge of the quadrangle. This is really a double-peaked anomaly; the more northerly peak has an amplitude of 250 gammas and is underlain by hornblende-granite gneiss; the southern peak has an amplitude of 150 gammas and is underlain by Hardyston quartzite. Both of these rock units have local concentrations of magnetite in disseminated form; a relatively small amount of the mineral, accentuated in effect by the topographic relief, is probably all that is responsible for the anomaly. No economic concentration of iron is indicated by the geologic conditions or by the anomaly.

A small anomaly occurs just west of Reiffton, along the eastern edge of the quadrangle. The anomaly is about a half mile in diameter and has an amplitude of 100 gammas; it is developed over a small area of hornblende gneiss which commonly has a few percent of disseminated magnetite present. Neither the size, the amplitude, nor the rock type offers any indication of a significant amount of iron mineralization.

The magnetic contour map shows a relatively gentle, positive anomaly which extends across the southerly portion of the quadrangle from Seidel Hill on the east to a point just south of Mohnton on the west. The anomaly is developed over the outcrop of a steep, north-dipping diabase dike which has cut through Triassic sedimentary rocks just south of where they are in contact with Paleozoic limestones. There is a belt of limestone conglomerate within the Triassic shale and sandstone sequence in this area. The combination of Paleozoic limestones, Triassic limestone conglomerate, and diabase intrusives makes this an area where one might consider the possibility of replacement type of mineral deposits within the limestones. In other areas of the Triassic belt, where such a combination of geologic formations exist, mineral deposits have been found, especially magnetite. The fact is that this area south of Reading does have a record of known mineralization. In the 1850's the Fritz Island Mine was developed in magnetite ore which was found in the Triassic limestone conglomerate as well as the adjacent Paleozoic limestone; apparently, mineralizing solutions related to the diabase introduced the magnetite as replacement material. The Fritz Island Mine was a fairly extensive underground operation with two shafts reaching a depth of nearly 280 feet and with several work levels developed. The ore lode had a dip of about 45° under the river, and a maximum thickness of 22 feet. Two hundred fifty thousand tons of ore were produced here up to 1883. There is some question as to whether mining was discontinued because of poor ventilation or poor ore. The aeromagnetic map does not indicate that any significant quantity of iron ore was left unmined at the Fritz Island Mine or in the immediate vicinity. Even if there were appreciable ore at Fritz Island, the sewerage plant, the general urbanization of the locality, and the problems of working under the river would prove to be virtually insurmountable.

A half mile west of the Fritz Island Mine the Raudenbush Mine was dug near the contact between Triassic limestone conglomerate and diabase. It is reported (D'Invilliers, 1883) to have produced at least 5000 tons of ore a year. The ore occurred as a south-dipping vein of magnetite of variable thickness but averaging less than 12 feet. The magnetite ore solutions apparently replaced the carbonate rock. On the magnetic map, a half mile east of the town of Grill (south of Reading) is a small, positive magnetic anomaly which marks the site of the Raudenbush Mine. The anomaly has an amplitude of 200 gammas. The presence of the anomaly indicates some magnetite still exists there, but the small amplitude indicates that neither the grade nor the size of the mineral concentration is appreciable. From the accounts of the old Raudenbush Mine, it is questionable if the ore zone which they then were mining would be usable on the basis of modern mining methods and mineral economics. Thus, the overall indications here at the site of the old Raudenbush Mine, just as at the Fritz Island location, does not indicate economically significant iron mineralization.

It is noteworthy that Neversink Mountain, a very pronounced topographic high just southeast of Reading, shows no related magnetic anomaly. This mountain is made up of Hardyston quartzite and granite gneiss, not unlike Mount Penn and Irish Mountain, though the latter two do have associated magnetic anomalies. It is possible that Neversink Mountain may be structurally unlike the other mountains, possibly lacking a crystalline root.

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Birdsboro Quadrangle
U. S. Geological Survey Aeromagnetic Map G.P. 231

The Birdsboro quadrangle aeromagnetic map shows a few prominent magnetic anomalies which are developed over igneous and metamorphic rocks in the western half of the quadrangle. The eastern half of the quadrangle shows a very simple magnetic pattern with only a few, widely spaced contour lines; this is an area underlain by Triassic sediments to the south and by Cambro-Ordovician sediments to the north.

The most prominent positive magnetic anomaly of the quadrangle occurs over Pine Ridge and Kinsey Hill in Exeter Township in the west-central part of the quadrangle. The anomaly is over 2 miles long and has an amplitude of 1000 gammas. The anomaly occurs over a thick, intrusive sheet of diabase, a dense, erosion-resistent rock mass which is responsible for Pine Ridge and Kinsey Hill. The diabase is composed in part of iron silicate minerals and also contains some accessory magnetite; the magnetic intensity of this mineral assemblage, accentuated by the topography of the ridge, may be responsible for the anomaly. However, Spencer (1908) reports that magnetite was mined at the Esterly Mine at this location 2 miles south of Jacksonwald; the ore was found at the contact between the north-dipping diabase sheet and the underlying Triassic sediments. This was not an extensive mine, only 3000 to 4000 tons of ore reportedly being mined. The magnetite ore apparently developed by replacement of the somewhat calcareous shales under the diabase. Within the old Esterly Mine it is reported that the ore extended for only 100 feet in an east-west direction, but its limit down slope was not established; the shaft went down for only 125 feet. The presence of calcareous shale and the existence of limestone conglomerate only a few hundred feet away from this diabase intrusive present a relatively favorable environment for localization of any mineral solutions which might have been associated with the diabase. The 1000 gammas amplitude of the Pine Ridge-Kinsey Hill anomaly is somewhat higher than is generally found associated (300-700 gammas) with the diabase in this part of the state. This suggests that either there is a somewhat higher percentage of disseminated accessory magnetite throughout the diabase of this ridge, or else some magnetite exists as a layer or zone next to the diabase, as in the case of the Esterly Mine. In either case, the situation is not particularly encouraging; it would take relatively little additional, disseminated magnetite in the diabase to account for the size of the anomaly and similarly, a thin, relatively lean layer of magnetite next to the diabase could have the same effect. Neither of these situations would be likely to make an iron concentration of minable grade.

It is noteworthy that the Pine Ridge-Kinsey Hill anomaly is developed only over the segment of the diabase sheet which dips north; where the diabase swings around and dips southward (opposite to the natural plunge of the earth's magnetic lines at this part of the world) the magnetic map shows very little magnetic effect. It may also be observed that an adjacent, parallel sheet of extrusive basalt, presumably genetically related to the diabase, shows no manifestations on the magnetic map either over its north or sourth dipping segments.

In the southwestern corner of the quadrangle, elongate positive magnetic anomalies are developed over Sheep Hill and Cedar Hill; these ridges are topographic expressions of a continuous, steep, north-dipping diabase sheet which extends onto the adjacent quadrangles. These anomalies have amplitudes of about 700 gammas. The diabase contains some disseminated magnetite as well as numerous iron silicate minerals; the field and map evidence indicates that the magnetic effect of these minerals, accentuated by the topography, is responsible for these anomalies. Neither the geologic data nor the magnetic data suggests any economically significant iron concentration here.

In the northwest corner of the quadrangle a positive magnetic anomaly occurs in Alsace Township, about a mile north of Antietam Reservoir. The anomaly trends northeasterly, is about a mile long, and has an amplitude of about 300 gammas. The anomaly is developed over a mass of granitic gneiss which forms a topographic high. This rock type is widespread in the area and quite variable in composition; locally it shows concentration of hornblende as well as disseminated magnetite. Such a mineral assemblage, coupled with the topographic effect, can readily account for this relatively small anomaly. No significant concentration of iron is indicated here.

A prominent positive magnetic anomaly occurs along the northern edge of the quadrangle, just east of Spies Church in Alsace Township. The anomaly is only about a half mile in diameter but has an amplitude of over 1000 gammas. The anomaly occurs over the flank of a knob made up of dark, hornblende-rich gneiss which is surrounded by lighter-colored, granitic gneiss. Field examination to date has revealed extremely little accessory magnetite in the rocks at the surface; the anomaly suggests a more pronounced concentration of magnetite at a shallow depth, though it is impossible to figure the actual degree of concentration. It would require more exploratory work, possibly including some drilling, to fully assess the origin of this anomaly. The limited diameter of the anomaly tends to be a discouraging factor as far as the potentiality of large size or tonnage of the source material is concerned.

A positive magnetic anomaly occurs in Exeter Township, a half mile west of Oley Line; the anomaly trends in a north-northeasterly direction, is about a mile long, and has an amplitude of 200 gammas. This anomaly is developed over a low hill of granitic gneiss. The gneiss exhibits considerable variation in mineral content and locally has concentrations of hornblende and small amounts of disseminated magnetite; such a situation,accentuated by the topography, readily accounts for this anomaly. No economic concentration of iron is indicated here.

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Boyertown Quadrangle
U. S. Geological Survey Aeromagnetic Map G. P. 232

The variation of magnetic patterns on the Boyertown magnetic map shows a marked correlation with the major rock types. The northern half of the quadrangle exhibits numerous magnetic anomalies of various sizes, shapes, and orientations; this is an area underlain by old, crystalline gneisses with some infolded and infaulted areas of Cambrian quartzite.

The southern half of the quadrangle exhibits few, widely spaced magnetic contours; this area is underlain by Triassic sandstones and shales.

The Triassic igneous rocks and associated mineralization is well defined by the prominent magnetic pattern in the east-central portion of the map.

Along the northern edge of the quadrangle, 2 miles west of Bechtelsville, are two positive magnetic anomalies, one just southwest of the other. These anomalies are each about a half mile in diameter with amplitudes of approximately 400 gammas. The underlying rock is granitic gneiss which locally carries small concentrations of disseminated magnetite. The northeast-southwest orientation of these two anomalies is parallel to the trend of the foliation and suggests the presence of a layer with some magnetite. However, neither the amplitude of the anomalies nor the lithologic character of these rocks offers encouragement as to the likelihood of significant amounts of iron here.

A pronounced positive magnetic anomaly trends southwest from Bechtelsville for nearly 5 miles. Near Bechtelsville it is about a half mile wide but at its southwestern end (near Long Hill) it broadens out to a mile in width and an amplitude of 800 gammas. Along its entire length this anomaly occurs over-hornblende-bearing gneiss which also carries some disseminated magnetite. It is noteworthy that this magnetic feature not only parallels the trend of the gneissic foliation, but it is parallel to (and on the south side of) a major fault zone. The southwestern end of this anomaly is parallel to Long Hill, a ridge held up by downfaulted, erosion resistent Harydston quartzite. The northwest trending cross-faults which mark the southwest and northeast ends of the Long Hill quartzite, also mark the southwest end of the anomaly as well as the point further to the northeast where the anomaly abruptly becomes narrower. These relationships indicate that the zone which is responsible for the anomaly has been involved in the Paleozoic structural deformation of the area. Though this is a pronounced anomaly indicating a zone which must have some concentration of iron, probably in the form of magnetite, it is unlikely that this anomaly of less than 1000 gammas amplitude in a crystalline environment is due to anything more than a band of relatively lean, disseminated magnetite. The anomaly probably defines a feature of structural and petrographic interest rather than one of economic significance.

A positive magnetic anomaly occurs in the northwest portion of the quadrangle between Stone Cave Hill and Saenger Hill in Earl Township. This magnetic feature trends north and manifests peaks near Woodchoppertown, Furnace Hill, and Shenkel Hill. The trend of this complex magnetic feature corresponds with the basal contact between a north trending belt of Hardyston quartzite and the adjacent hornblende-bearing gneiss; even the offsets of the contact due to cross-faults are reflected by the magnetic feature. The maximum amplitude of 300 gammas virtually eliminates the possibility of any commercial concentrations of iron ore but the origin of this magnetic anomaly is a matter of academic interest. The phenomenon of a positive magnetic anomaly along the Hardyston-gneiss contact occurs at several localities in the Reading Prong area. While the gneiss may be observed to carry magnetite many places in this region, the repeated occurrence of magnetic anomalies along Hardyston quartzite-gneiss contact suggests the possibility of a zone of magnetite in the basal conglomerate of the Hardyston quartzite. In none of these situations, however, is a concentration of commercial scope indicated.

In the east-central part of the Boyertown magnetic map a pronounced magnetic feature may be observed over Boyertown and extending south and southeast toward Upper Pottsgrove. The portion of the positive anomaly about a half mile wide extending south and southeast from the Colebrookdale-Douglass Townships line is developed over the outcrop belt of a northeast-dipping sheet of diabase which has intruded the Triassic sediments. The diabase and the anomaly extend onto the adjacent Sassamansville quadrangle.

The diabase is partly composed of iron silicate minerals as well as some disseminated magnetite. The 500 gammas amplitude of this anomaly over the diabase is within the range commonly found over other diabase masses in this part of the state. Though some relatively minor contact metamorphic effects are noted along the contact between the diabase and the Triassic sandstones and shales, the anomaly along the Marysville-Colebrookdale-Cedar Grove belt can be attributed primarily to the diabase, with no indications of economic iron concentrations.

At the southern edge of the city of Boyertown is the center of a broad, nearly circular positive magnetic anomaly; this anomaly appears on the magnetic map to be connected to the northern end of the linear anomaly attributable to the diabase. The diameter of the circular anomaly is about a mile and a half; the amplitude is a little over 500 gammas. The circular Boyertown anomaly occurs at the site of the old Boyertown mines. Spencer (1908) and D'Invilliers(1883) give extensive descriptions of the complex workings involving five ore bodies clustered together at Boyertown. An extensive network of shafts and tunnels existed here in the 1880's; a maximum depth of over 660 feet was achieved in the mining. Though the surface rock in Boyertown is Triassic sediments, the ore was found as replacements of Paleozoic limestone which underlies the Triassic rocks; the Triassic-Paleozoic contact dips southeast at Boyertown and the ore horizons beneath the Triassics also dipped southeast. It has been variously suggested that the five orebodeis may be interconnected at depth or that they may be segments of one original ore horizon which was offset by faulting. The ore horizons at Boyertown, while essentially tabular or lenticular, tended to pinch and swell, reaching maximum thickness of 40 feet.

The geologic conditions in the Boyertown area were extremely favorable for the localization of ore deposits. The upper Triassic diabase intrusives came into close proximity with Paleozoic limestones as well as Triassic limestone breccias; thus, carbonate host rocks were available for replacement by ore solutions.

The history of successful mining, as well as the fairly extensive belt of favorable geologic conditions, has brought about renewed interest in the possibilities of the Boyertown area. In 1916-1917 the Boyertown Ore Company did some dewatering of the old mines and put down four drill holes; one vertical hole encountered 13 feet of ore at a depth of 954 feet. In 1943-1944 the U. S. Geological Survey and the U. S. Bureau of Mines engaged in geologic and magnetic surveys around Boyertown; the U. S. Defense Plant Corporation put down two drill holes. Hawkes (1953) reports one vertical drill hole encountered 23 feet of ore at 612 feet depth which would average about 16 percent removable iron; the second vertical hole encountered 33 feet of ore at 1170 feet depth which would average about 23 percent removable iron.

Ground magnetic surveys in Boyertown city limits were rendered essentially useless by the magnetic effects of buildings and man-made features. The airborne magnetometer survey of 1944 indicated the locations of the old mines in Boyertown,particularly the Gabel and Warwick Mines. Northeast of Boyertown, however, the ground magnetic surveys indicated two possible small orebodies about 5000 feet northeast of New Berlinville, near the site of the old Fegley Mine (Sassamansville quadrangle). Southwest of Boyertown the 1944 ground magnetics indicated a possible small orebody along the edge of the diabase 1500 feet southwest of the old Boyertown mines; the old Brower Mine 3000 feet southwest of Boyertown also showed a little ore left.

The geologic,magnetic, and drilling data at Boyertown show some iron mineralization still exists there; the problem is how rich is it and how large. The old drilling data cited above is not encouraging as to continuity and grade of the ore zones at Boyertown. The 500 gamma anomaly on the new magnetic map (G. P. 232) is also not very encouraging for an iron mine here. It is of considerable academic interest, however, that the anomaly at Boyertown is so broad, extending eastward over the Triassic rocks and westward across the Paleozoics and on over the crystallines for a half mile; this suggests the possibility of some large, structural unit.

Along the southern edge of the Boyertown quadrangle, about a mile west of Stowe, a broad, gentle positive anomaly occurs. This magnetic feature is underlain by mass of diabase whose iron-bearing minerals readily account for the anomaly. Neither the rock type nor the 100 gamma anomaly indicate any significant iron mineralization.

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